5

Fishes of the Upper Klamath Basin

The upper Klamath basin is an ancient, isolated, and unusual environment for fish. Most, or possibly all, of the native species that live in the upper basin are endemic to it. The distinctiveness of the upper basin and its fishes has been recognized since the first ichthyologists explored it in the late 19th century (Cope 1879, Gilbert 1898), but the application of new kinds of genetic analysis to the fishes is revealing even more diversity and complexity than was previously known (e.g., Docker et al. 1999, Tranah 2001).

Since the shortnose and Lost River suckers were listed as endangered species in 1988, a great deal of attention has been paid to their biology, especially in Upper Klamath Lake, whereas the rest of the species and the rest of the basin have received comparatively little attention. The other endemic fishes, some of which may be considered for listing in the future, interact with the endangered suckers and thus complicate management practices intended to benefit them. In addition, nonnative fishes, which are abundant in the basin, affect the endangered suckers. Overall, the upper basin's land and water should be managed through an ecosystem-based approach with all native fishes in mind under the assumption that management favoring native fishes is likely to have positive effects on other ecosystem components. Failure to do this is likely to result in listing of additional species as threatened or endangered. The purposes of this chapter are to describe the factors that led to the high endemism of fishes in the upper Klamath basin and to its invasion by nonnative fishes, to give a brief summary of the biology and welfare of each of the native fishes with special attention to the listed suckers, an overview of the nonnative fishes, and to identify gaps in knowledge about all the fishes.

NATIVE FISHES

The fishes of the upper Klamath basin originated when a large river draining the western interior of North America flowed through the Klamath region on its way to the ocean (Minckley et al. 1986, Moyle 2002). Uplift and erosion have since caused the water in the region to flow at different times into the Great Basin to the east, into the Columbia River via the Snake River to the northwest, into the Sacramento River via the Pit River to the south, and into the lower Klamath River to the west. As the connections to large drainage basins shifted back and forth, fishes from each of the basins entered the upper Klamath basin (Minckley et al. 1986, Moyle 2002). Species that persisted through periods of change, which included drought and volcanism, evolved into the endemic fauna of the upper Klamath basin (Table 5-1). These fishes are adapted to the shallow lakes, meandering rivers, and climatic extremes of the upper Klamath basin. The closest relatives of modern fishes of the upper Klamath basin are now found in the Great Basin, Columbia River, Pit River, and lower Klamath River.

The present connection of the upper Klamath basin to the lower Klamath basin probably is fairly recent (Pleistocene, less than 1.8 million years BP), but the connection formed and was blocked more than once. Connection of the upper and lower basins led to colonization of the upper basin by anadromous Chinook salmon, steelhead, and Pacific lampreys. Repeated isolation of anadromous fishes when the connection between the two parts of the Klamath basin was broken left behind resident populations that now differ from parent stocks (such as redband trout and Klamath River lamprey).

The lower basin contains mainly fast-flowing, cool-water rivers and streams that are ideally suited for anadromous fishes but inhospitable to fishes of the upper basin, which are adapted to lakes or warmer streams and rivers of lower gradient. Thus, the two basins have remarkably different fishes. The absence of major physical barriers to movement of fish before installation of dams explains the former use of the upper basin by anadromous fishes and the apparent occasional entry into the upper basin of the Klamath smallscale sucker, which is abundant in the lower basin.

Only five families of fishes—Petromyzontidae, Cyprinidae, Catostomidae, Salmonidae, and Cottidae—are native to the upper basin, and the species in these families have many unusual adaptations to the environment of the basin. The lampreys and suckers of the upper basin show some interbreeding (hybridization) among species.

Petromyzontidae: Lampreys

The lampreys of the upper Klamath basin are all derived from anadromous Pacific lampreys that became land-locked, perhaps multiple times over millions of years. Their evolution and ecology are poorly understood. Four species are recognized (Docker et al. 1999, Lorion et al. 2000, Moyle 2002), but additional species may be uncovered as genetic studies proceed. There are two basic life cycles among lampreys: one with predatory adults and one with nonpredatory adults. Both types spend the first 3-7 yr of their lives living in mud and sand as eyeless, wormlike larvae (ammocoetes) that feed on algae and organic matter. The ammocoetes metamorphose into silvery, eyed adults. Adults of the predatory forms attach to other fish with their sucking-disc mouths, through which they remove blood and body fluids. Typically the prey survives the attack of a predatory lamprey, but the attack may impair growth and survival (Moyle 2002). Predatory lampreys engage for about a year in this feeding behavior, which enables them to grow to produce a larger number of gametes than do nonpredatory lampreys. The adults of the nonpredatory form do not feed; they live only long enough to reproduce (Moyle 2002).

The **Pacific lamprey** is regarded as a land-locked version of the predatory anadromous species, but the form native to the upper Klamath basin probably should be a separate taxon.

Table 5-1. Native Fish Species of the Upper Klamath Basin

Species	Adult Habitat[a]	Status[b]	Comments
Pacific lamprey, *Lampetra tridentata*	R, L	C?	Same species as in lower river but land-locked and probably distinct
Klamath River lamprey, *L. similis*	R	C	Also in lower river
Miller Lake lamprey, *L. milleri*	R, L, W	U	Once thought extinct
Pit-Klamath brook lamprey, *L. lethophaga*	W, C	C?	Shared with Pit River
Klamath tui chub, *Siphatales bicolor bicolor*	L, R, W	A	Abundant and widespread
Blue chub, *Gila coerulea*	R, W	C	Special concern species in California
Klamath speckled dace, *Rhinichthys osculus klamathensis*	W, C, R, L	C?	May be more than one form
Shortnose sucker, *Chasmistes brevirostris*	L, R	L	Listed as endangered
Lost River sucker, *Deltistes luxatus*	R, L	L	Listed as endangered
Klamath largescale sucker, *Catostomus snyderi*	R, L, W	C?	May be more than one form; declining?
Klamath smallscale sucker, *C. rimiculus*	R, W, C	R	Common in lower basin
Klamath redband trout, *Oncorhynchus mykiss* subsp.	R, L	C?	Fishery; may be more than one form: lake and stream
Coastal steelhead, *O. mykiss irideus*	R, C	E	Anadromous, common in lower basin
Chinook salmon, *O. tshawytscha*	R	E	Anadromous, common in lower basin
Bull trout, *Salvelinus confluentus*	C	L	Threatened species
Upper Klamath marbled sculpin, *Cottus klamathensis klamathensis*	C, W, R	C	Widespread in basin
Klamath Lake sculpin, *Cottus princeps*	L, R	A	Abundant in Upper Klamath Lake
Slender sculpin, *Cottus tenuis*	L, R	R	Gone from much of former range

[a]Adult habitat: L, lakes; R, river; W, warm-water creeks; C, cold-water creeks.
[b]Status in upper basin: A, abundant; C, common; E, extirpated; L, listed under federal Endangered Species Act; R, rare; U, unknown.

Nothing is known about its ecological differences from the slightly smaller (14-27 cm) **Klamath River lamprey.** The Klamath River lamprey is a nonmigratory predatory species that is widespread in the upper and lower basins. Little is known about its biology except that it preys on native suckers and cyprinids, especially in reservoirs (Moyle 2002). The **Miller Lake lamprey** is the smallest (less than 15 cm) predatory lamprey known anywhere in the world; it occurs mainly in the Sycan and Williamson rivers, where resident prey species are abundant (Lorion et al. 2000). The Miller Lake lamprey is closely related to the nonpredatory **Pit-Klamath brook lamprey**, which is abundant and widespread in small streams in the upper Klamath and Pit River basins. Because of the long (about1 million years) separation of the Pit and Klamath basins, genetic studies will probably show that the two populations belong in different taxa. The exact distribution of the four species in the watershed is not known, because most collections are of ammocoetes, which are difficult to identify in the field.

Cyprinidae: Minnows

The **Klamath tui chub** is widespread in the interior basins of the western United States and is divided into a number of subspecies (Moyle 2002). Some, including the Klamath tui chub, may eventually be recognized at the species level. Tui chubs are chunky, omnivorous minnows that can become large (about 30 cm) and have high longevity (20-35 yr), especially in large lakes. In the Klamath basin, they are the most abundant and widely distributed native fish. They occur in streams, rivers, reservoirs, and lakes (Simon and Markle 1997a,b; Buettner and Scoppettone 1991) and in a wide array of habitats (Bond et al. 1988). They are tolerant of high temperature (over 30°C), low dissolved oxygen (below 1 mg/L), and high pH (10-11; Falter and Cech 1991, Castleberry and Cech 1992, Moyle 2002). Despite those tolerances, they typically are among the most abundant species in fish kills of Upper Klamath Lake (Perkins et al. 2000b), although counts of dead chubs usually do not distinguish tui chubs from blue chubs. In the last 30 years, the tui chub has declined in abundance in the Lost River, where it has changed from a dominant member to a minor component of the fish fauna (Shively et al. 2000a).

In contrast with tui chub, the **blue chub** is confined largely to the Klamath basin and a few adjacent basins into which it may have been introduced (Moyle 2002). It is especially abundant in lakes, reservoirs, and other warm, still habitats (Bond et al. 1988, Buettner and Scoppettone 1991). It may be the most abundant native fish in Upper Klamath Lake, although it may also be in decline there, along with most other native fishes (Simon and Markle 1997b, Moyle 2002). It clearly is in decline elsewhere in the upper Klamath basin. For example, Contreras (1973) found that the blue chub was the most abundant species in the upper part of the Lost River but that the tui chub was the most abundant in the lower half of the river. More recent sampling indicates that both species have been largely replaced by fathead minnows, brown bullheads, and other nonnative species that tolerate poor water quality (Shively et al. 2000a). Not much is known about the biology of the blue chub except that it is omnivorous, schools, and reaches a length of about 25 cm. It is somewhat less tolerant of high temperatures and low dissolved oxygen than the tui chub (Castleberry and Cech 1992) and is common in fish kills of Upper Klamath Lake (Perkins et al. 2000b).

The **speckled dace** is even more widespread than the tui chub in western North America and probably consists of a complex of species (Moyle 2002). Dace from both the upper and lower Klamath basins are recognized as just one subspecies, but the two forms probably are distinct, and the upper basin probably supports more than one taxon (M. E. Pfrender, Utah State University, personal communication 2002). The speckled dace is common in the upper basin but is most abundant in cool streams associated with rocks and gravel (Buettner and Scoppettone

1991, Bond et al. 1988). Even so, Castleberry and Cech (1992) found that it could withstand high temperatures (28-34°C) and low concentrations of dissolved oxygen (1-3 mg/L). The status of the speckled dace in the basin is not known, because collections are biased toward the larger fishes. It apparently has become very uncommon in the Lost River, however (Shively et al. 2000b).

Catostomidae: Suckers

The four species of suckers in the Klamath basin (Table 5-1) have an interesting and long evolutionary history (Moyle 2002) and probably once were the most abundant fishes, in terms of biomass, in the lakes and large rivers. The listed **shortnose sucker** and **Lost River sucker**, which have been the focus of most fish studies in the upper basin, will be treated in the last part of this chapter. The **Klamath smallscale sucker** is rare (or perhaps absent since the construction of Copco Dam) in the upper basin, although it is found in upper Jenny Creek, a tributary to Copco Reservoir. It is abundant in the lower basin (see Chapter 7). The **Klamath largescale sucker** is resident in the upper basin. All four species show some evidence of hybridization with each other (Tranah 2001).

The Klamath largescale sucker, which becomes large (about 50 cm) and has a long lifespan (31 yr or more), as do the shortnose and Lost River suckers, is one of the least understood fish in the basin (Moyle 2002). It appears to be mainly a resident of large rivers, although a small population exists in Upper Klamath Lake, and it is rare or absent in the Lost River (Koch et al. 1975, Buettner and Scoppettone 1991, Shively et al. 2000a). It apparently is common and widely distributed in the Williamson, Sprague, and Wood rivers (Reiser et al. 2001). In Upper Klamath Lake, the Klamath largescale sucker is found mainly near inflowing streams; this suggests a low tolerance for lake conditions, but it has been found at temperatures near 32°C in environments of dissolved oxygen at 1 mg/L and pH over 10 (Moyle 2002). Lake populations of largescale suckers migrate for spawning in March and April; peak spawning activity occurs a month or so earlier than that of shortnose and Lost River suckers. Radio-tagged fish have migrated as far as 128 km upstream, presumably to find gravel for spawning (Reiser et al. 2001). The Klamath largescale sucker hybridizes with the shortnose and Lost River suckers. Genetic studies by Tranah (2001) suggest that the largescale suckers in the Sprague River belong to a different taxon from other largescale suckers in the basin.

The status of the Klamath largescale sucker is poorly understood. The lake populations probably are similar to those of the shortnose and Lost River suckers in having declined in abundance. The status of stream populations is not known, although they are assumed to be widespread and abundant (Reiser et al. 2001).

Salmonidae: Salmon and Trout

The **bull trout** is a predatory char that is widely distributed in the northwestern United States but is considered a relict species in the Klamath basin. It apparently entered the Klamath basin when it was connected to the Snake River but then became isolated. Genetic evidence reflects isolation and suggests that the bull trout of the upper Klamath basin could be assigned to a distinct taxon or evolutionarily significant unit (Ratliff and Howell 1992). The bull trout is known from only 10 creeks in the upper Klamath basin—four tributaries to the Sprague River, four to the Sycan River, and two to Upper Klamath Lake (Ratliff and Howell 1992, Buchanan et al. 1997)—although it has been extirpated or is at risk of extirpation in most of these creeks. An important characteristic of streams containing bull trout is high water quality; temperatures do not exceed 18°C in these streams (Moyle 2002). The bull trout tends to disappear from streams with degraded water quality even if the streams can support other kinds of trout. The bull trout also declines when the brook trout invades its habitat. Hybridization between the bull trout and the brook trout has taken place in some Klamath basin streams (Markle 1992). Threats to the existence of the bull trout are not peculiar to the Klamath basin; they occur throughout its range. Thus, the bull trout of the upper Klamath basin was listed by the U.S. Fish and Wildlife Service (USFWS) in 1998 as threatened.

The bull trout, like the endangered suckers of the upper basin, demands special attention in the future. Unlike the suckers, however, the bull trout is spatially separated from the Klamath Project and most other water management because its distribution is restricted primarily to headwaters that are remote from Upper Klamath Lake or the lower reaches of tributaries that are so important to suckers. At present a good deal of attention is being given to the welfare of bull trout, but much work remains to be done.

The **redband trout** is a resident rainbow trout whose ancestors entered the upper Klamath basin when it was connected to the Columbia Basin via the Snake River (Behnke 1992). Coastal rainbow trout (steelhead) later entered the upper basin, but the redband trout derived from the Columbia Basin maintained its identity and is recognizable by its morphology and color. Behnke (1992) indicates that there are two types of redband trout in the basin: a small form resident in isolated streams and the form present in Upper Klamath Lake; he suggests that the lake form is so distinctive (for example, it has large numbers of gill rakers, an adaptation to life in lakes) that it deserves subspecies designation (as *O. m. newberrii*). The Oregon Department of Fish and Wildlife (ODFW), however, regards all redband trout in the interior basins of Oregon as belonging to one taxon, even though it states that the Klamath Lake redband trout is "unique in terms of life history, meristics, disease resistance, and allozyme variation" (Bowers et al. 1999). The various stream populations in the basin also show genetic evidence of isolation from one another (Reiser et al. 2001). Regardless of taxonomic position, these fish have persisted because of their ability to thrive in lake and stream conditions that would be lethal to most salmonids.

Behnke (1992) wrote of observations he made on Upper Klamath Lake in September 1990 (p.181): "In clear-water sections influenced by spring flows, hundreds of large, robust trout from about 1 to 5 kg could be readily observed. In shallow (2 m) Pelican Bay, in the midst of a bloom [of bluegreen algae] (I estimated a Secchi disk clarity of about 40 cm), I caught a magnificent trout of 640 mm and 2.3 kg." This is consistent with continuing reports of a strong summer fishery for trout, especially in Pelican Bay (e.g., Hoglund 2003). Water temperatures in Upper Klamath Lake in summer are 20-25°C, occasionally spiking to 27°C, and dissolved oxygen may drop below 4 mg/L for several days (Perkins et al. 2000b). Springs and the mouths of streams in Pelican Bay, which apparently have higher water quality than the lake, may serve as refuges for the trout, especially during episodes of very poor water quality in the lake. Trout have been reported in the lake's summer fish kills, but the only example of mass mortality was in 1997, when about 100 large trout were found dead (Perkins et al. 2000b).

The lake population of redband trout is adfluvial; it migrates up into the Wood, Williamson, and Sprague rivers for spawning during spring. The rivers also support resident populations of these trout, as does the river below Upper Klamath Lake, mostly above Boyle Dam (Bowers et al. 1999). Isolated populations, which are genetically distinct from the Klamath Lake and river populations, exist in the upper Williamson and Sprague rivers and in Jenny Creek, which flows into Iron Gate Reservoir (Bowers et al. 1999).

Hatchery rainbow trout (coastal stock) in the past have been stocked in Klamath basin streams, and some interbreeding with native redband trout was noted. Stocking now is limited to Spring Creek, which flows into the lower Williamson River. The hatchery fish apparently have poor survival because they are not resistant to endemic disease and are not adapted to high pH (Bowers et al. 1999).

Redband trout are doing surprisingly well in the Klamath basin, considering all the changes that have taken place. The fishery for the lake and river populations is an important recreational resource. The populations of small streams are vulnerable, however, to habitat degradation by roads, grazing, and other activities. The lake and river populations will need protection from adverse water quality and nonnative species and probably would benefit from improved habitat in the rivers and improved access to upstream habitat (Bowers et al. 1999).

Cottidae: Sculpins

The sculpins are a poorly studied group in the Klamath basin despite the presence of at least three endemic species (Klamath Lake sculpin, slender sculpin, and Upper Klamath marbled sculpin). There may be additional taxa in the watershed as well (Bentivoglio 1998).

The **Klamath Lake sculpin** apparently is the most abundant sculpin in Upper Klamath Lake. It is caught in large numbers in the lake with bottom trawls (D. Markle, Oregon State University, personal communication, 2001) and in smaller numbers with beach seines and trap nets (Simon and Markle 1997b). The abundance of this sculpin is estimated to be in the millions (Simon et al. 1996). It is present only in Upper Klamath and Agency lakes and in springs and creeks that flow into the west side of Upper Klamath Lake (Bentivoglio 1998). The present distribution coincides with the known historical distribution of the species. Little is known about its environmental requirements, but it lives mainly in offshore areas with bottoms of sand and silt and appears to be able to withstand widely varied lake conditions. No Klamath Lake sculpins have been reported in the fish kills of Upper Klamath Lake, but dead fish of this species would not float and so would be easy to overlook. The apparent ability of the Klamath Lake sculpin to live in conditions of poor water quality (especially low dissolved oxygen) is similar to that of prickly sculpin (*Cottus asper*) in Clear Lake of central California which, like Upper Klamath Lake, is subject to massive blooms of cyanobacteria (Moyle 2002).

The **slender sculpin** apparently once was common in the Williamson, Sprague, Sycan, and Lost rivers and in Upper Klamath Lake (Bentivoglio 1998). Bentivoglio (1998) collected sculpins throughout the upper basin in 1995-1996, however, and found slender sculpins only in the lower Williamson River and a few in Upper Klamath Lake. Simon and Markle (1997b) also recorded small numbers in Upper Klamath Lake. Little is known about the ecology of this fish, although it seems to require coarse substrates and high water quality; it is especially characteristic of cold springs. Its closest relative is the rough sculpin (*C. asperimmus*) of the Fall River in California (Robins and Miller 1957), which requires cold, spring-fed streams (Moyle 2002). It is fairly long-lived for a sculpin (7 yr) but is small (rarely longer than 75 mm; Bentivoglio 1998). Overall, the slender sculpin appears to have disappeared from much of its native range and is uncommon in most areas where it is found today.

The **Upper Klamath marbled sculpin** is the most widely distributed sculpin in the Klamath basin (A. Bentivoglio, USFWS, personal communication, 2002). It is found in most streams and rivers in the basin in a wide range of conditions, including summer temperatures over 20°C (Bond et al. 1988). It is most abundant among coarse substrates in the larger streams where water velocities are moderate to low (Bond et al. 1988). In the Lost River basin, it is known mainly from riffles in Willow and Boles Creeks (Koch et al. 1975) but has become scarce in recent years (Shively et al. 2000a). It is largely absent from the reservoirs in the basin, at least in California (data in Buettner and Scoppettone 1991), but is fairly common in Upper Klamath Lake (Simon et al. 1996, Simon and Markle 1997b). It occurs mostly on soft bottoms in the lake and apparently enters the water column to feed at night (Markle et al. 1996). It has been recorded in at least one of the fish kills of Upper Klamath Lake (Perkins et al. 2000b). The marbled sculpin, like most stream sculpins, generally hides under or among rocks, where it feeds on benthic invertebrates (Moyle 2002). Females glue their eggs to the bottoms of rocks and logs where developing embryos are tended by males until they hatch. The larvae are benthic and do not move far from their natal site. They become mature in their second summer and live 4-5 yr (Moyle 2002). The details of their ecology and life history in the upper Klamath basin have not been described.

NONNATIVE FISHES

In the last century, the upper Klamath basin has been invaded by 17 nonnative species (Table 5-2), 15 of which were introduced for sport fishing or for bait. Most of the 17 are not particularly common in the basin, but some are abundant and widespread (or are spreading), and their effects on native fishes are poorly understood. One of the most recent invaders is the fathead minnow, which is now one of the most abundant fishes in Upper Klamath and Agency lakes (Simon and Markle 1997a). The Sacramento perch, which was introduced into Clear Lake in the 1960s, has the potential to become very abundant in other lakes of the basin (Moyle 2002). Other introduced species—especially yellow perch, brown bullhead, and pumpkinseed—are locally abundant, especially in reservoirs and sloughs or ponds (Buettner and Scoppettone 1991, Simon and Markle 1997b). Brook trout, brown trout, and nonnative strains of rainbow trout are common in coldwater streams and have replaced native redband trout and bull trout in many areas. One concern is that future changes in water quality in the basin may promote further expansion of nonnative species.

The **fathead minnow,** which is native to eastern North America, appeared in the Klamath basin in the early 1970s, perhaps as a result of release of fish used in bioassay work (Simon and Markle 1997a). By 1983, it was common in Upper Klamath Lake and by the early 1990s it had

Table 5-2. Nonnative Fishes of the Upper Klamath Basin

Species	Adult Habitat[a]	Status[b]	Comments
Goldfish, *Carassius auratus*	L, R, P	U	Locally common
Golden shiner, *Notemigonus chrysoleucas*	L, R, P	R	Bait fish
Fathead minnow, *Pimephales promelas*	L, P	A	Probably still spreading
Brown bullhead, *Ameiurus nebulosus*	P, L, W	A	Widespread
Black bullhead, *A. melas*	P, L	U	Localized populations
Channel catfish, *Ictalurus punctatus*	L, R	?	May not be established
Kokanee, *Oncorhynchus nerka*	L	U?	Localized populations?
Rainbow trout, *O. mykiss*	L, R, C	C	Widely planted, hatchery strains
Brown trout, *Salmo trutta*	C, R	C	--
Brook trout, *Salvelinus fontinalis*	C	U	Localized in headwaters
Sacramento perch, *Archoplites interruptus*	L, P, R, W	C	Spreading
White crappie, *Pomoxis annularis*	L, R	U	Abundant in a few reservoirs
Black crappie, *P. nigromaculatus*	L, P	U	Recorded in Lost River
Green sunfish, *Lepomis cyanellus*	P, W	C	Widespread in reservoirs
Bluegill, *L. macrochirus*	P, W	U	Locally abundant
Pumpkinseed, *L. gibbosus*	L, R, P	C	Widespread
Largemouth bass, *Micropterus salmoides*	P, L, R	C	Common in reservoirs
Yellow perch, *Perca flavescens*	L, R, P	A	Abundant in large reservoirs

[a]Habitats are listed in order of importance for each species: C, cold-water streams; L, lakes; P, ponds and reservoirs; R, rivers; W, warm-water streams.
[b]Status in upper basin: A, abundant; C, common; R , rare; U, uncommon.

spread to the Lost River system (Simon and Markle 1997a, Shively et al. 2000a). It was collected in the lower Klamath River in 2002 (M. Belchik, unpublished memo). Fathead minnows often are the most abundant species at sampling sites. Their effects on other fishes are not well understood, although declines in catches of tui chub and blue chub have been associated with their ascendance.

The **Sacramento perch** is native to central California, where it has largely disappeared from its native habitats. It survives mainly when introduced into alkaline waters outside its native range (Moyle 2002). It was introduced by the California Department of Fish and Game into Clear Lake in the 1960s and spread throughout the Lost River and into the Klamath River downstream to Iron Gate Reservoir (Buettner and Scoppettone 1991). It is not particularly abundant in most areas where it is present. It has not yet established itself in Upper Klamath Lake. If it does colonize Upper Klamath Lake, it will probably become abundant there, as it has in other shallow lakes (Moyle 2002). It feeds primarily on insect larvae (especially midges), but adults can be piscivorous (Moyle 2002).

ENDANGERED SUCKERS OF THE KLAMATH BASIN

All four native sucker species of the Klamath basin are endemic. The endangered Lost

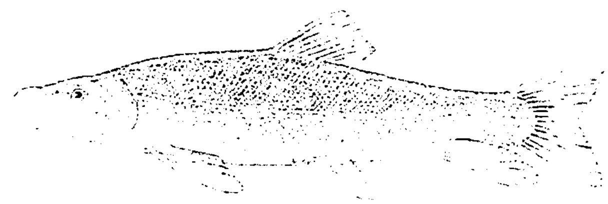
River sucker and shortnose sucker are part of a species group of suckers that are large, long-lived, late-maturing, and live in lakes but spawn primarily in streams; collectively, they are commonly referred to as lake suckers. Lake suckers populated much of the Snake River, Great Basin, and Lahontan Basin region (Miller and Smith 1981, Scoppettone and Vinyard 1991). Present-day species in the genus *Chasmistes* include not only the shortnose sucker (*C. brevirostris)* but also the cui-ui (*C. cujus*) of Pyramid Lake, Nevada; the June sucker (*C. liorus*); and a species that recently became extinct, the Snake River sucker (*C. muriei*) of Wyoming. Lost River suckers and shortnose suckers (Figure 5-1) are closely related to the more speciose and widely distributed sucker genus *Catostomus*; some recent taxonomic treatments place Lost River suckers in this genus (e.g., Moyle 2002).

The lake suckers differ from most other suckers in having terminal or subterminal mouths that open more forward than down, an apparent adaptation for feeding on zooplankton (small swimming animals) rather than suctioning food from the substrate (Scoppettone and Vinyard 1991). Zooplanktivory can also be linked to the affinity of these suckers for lakes, which typically have greater abundances of zooplankton than do flowing waters.

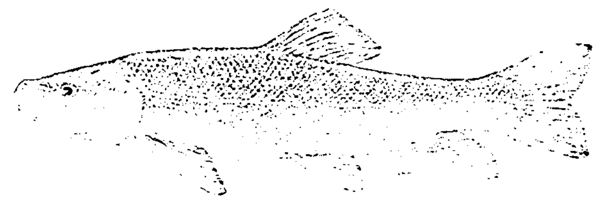
Historically, Lost River suckers and shortnose suckers occurred in the Lost River and upper Klamath River and their tributaries, especially Tule Lake, Upper Klamath Lake, Lower Klamath Lake, Sheepy Lake, and their tributaries (Moyle 2002, USFWS 2002 Appendix D). Their current distribution (Table 5-3; Figures 5-1 and 5-2) reflects a combination of local extirpations and redistribution through water management Suckers no longer occur in Lower Klamath Lake or Sheepy Lake, which were extensively drained in the 1920s; the populations in Tule Lake apparently do not reproduce successfully. Juveniles of Lost River and shortnose suckers have been found in much of the Lost River, but they probably originate in Miller Creek (Shively et al. 2000a). An additional population, probably consisting of shortnose suckers, was extirpated from nearby Lake of the Woods, Oregon, in 1952 when government agencies poisoned the lake to remove potential competition with trout (53 Fed. Reg. 27130 [1988]). The endangered suckers also are found in the mainstem reservoirs of the Klamath irrigation project (Chapter 3; Figure 1-4), but these populations appear to be nonreproducing (Desjardins and Markle2000, USFWS 2002). Reproducing populations exist in Clear Lake and perhaps the Lost River. Shortnose suckers also have a reproducing population in Gerber Reservoir (Moyle 2002, USFWS 2002).

Accounts of sucker distribution often are complicated by difficulties in distinguishing species, especially when the fish are young. Lost River suckers and shortnose suckers are partly distinguished from Klamath largescale suckers and Klamath smallscale suckers by greater maximum size. The Lost River sucker can be 26-40 in long, the shortnose sucker no longer than 21 in, the Klamath largescale sucker no longer than 18 in, and the Klamath smallscale sucker, a poorly studied species, at least 18 in. The Lost River sucker differs from the shortnose sucker and the Klamath largescale sucker with respect to some anatomical features of the head, mouth, lips, gill rakers, and body shape (Cunningham et al. 2002); it can generally be distinguished by its longer head and narrower, smaller mouth (see Figure 5-1).

The life histories of Lost River suckers and shortnose suckers are in some ways similar to those of anadromous salmon. Salmon spawn in fresh water and live most of their lives at sea before returning to their natal (birth) rivers to spawn and die. Similarly, the adults of the



A) Lost River Sucker



B) Shortnose Sucker

Figure 5-1. Endangered suckers of the Klamath River basin. (A) A Lost River sucker from Clear Lake; (B) a shortnose sucker from Clear Lake. Source: Drawings by A. Marciochi from Moyle 2002, pp. 199, 203. Reprinted with permission of the author.

endangered suckers commonly ascend from lakes to rivers to spawn, the eggs hatch in gravel, and the larvae float or swim downstream to lakes, where they grow and mature before returning to rivers or springs to spawn. Unlike salmon, lake suckers spawn repeatedly. It is not known which individuals return consistently to their natal rivers to spawn, but at least 50% do return at least one time to a river in which they have previously spawned (Cunningham et al. 2002). There are many exceptions to these generalizations. For example, some individuals or subpopulations spawn in lakes, whereas others live their entire lives in rivers or streams. The repeated spawning of the endangered suckers, combined with their exceptional longevity, allows individual adults to contribute to multiple year classes. Successful year classes are crucial to survival of both species, as explained below.

The requirements of the two species of endangered suckers are best understood in the context of their life-history stages, as described below. Unless a species-specific difference is indicated, the description of any given life-history feature is assumed to apply to both species. The quantity and quality of information on the species have increased substantially since the fishes were listed as endangered in 1988.

Spawning

Spawning occurs in tributary streams, in springs caused by upwelling of ground water in lakes, and around springs in rivers. The suckers may migrate as little as 2-4 mi up a stream from a lake (for example, up Willow Creek from Clear Lake), or over 20 mi (for example, up Boles

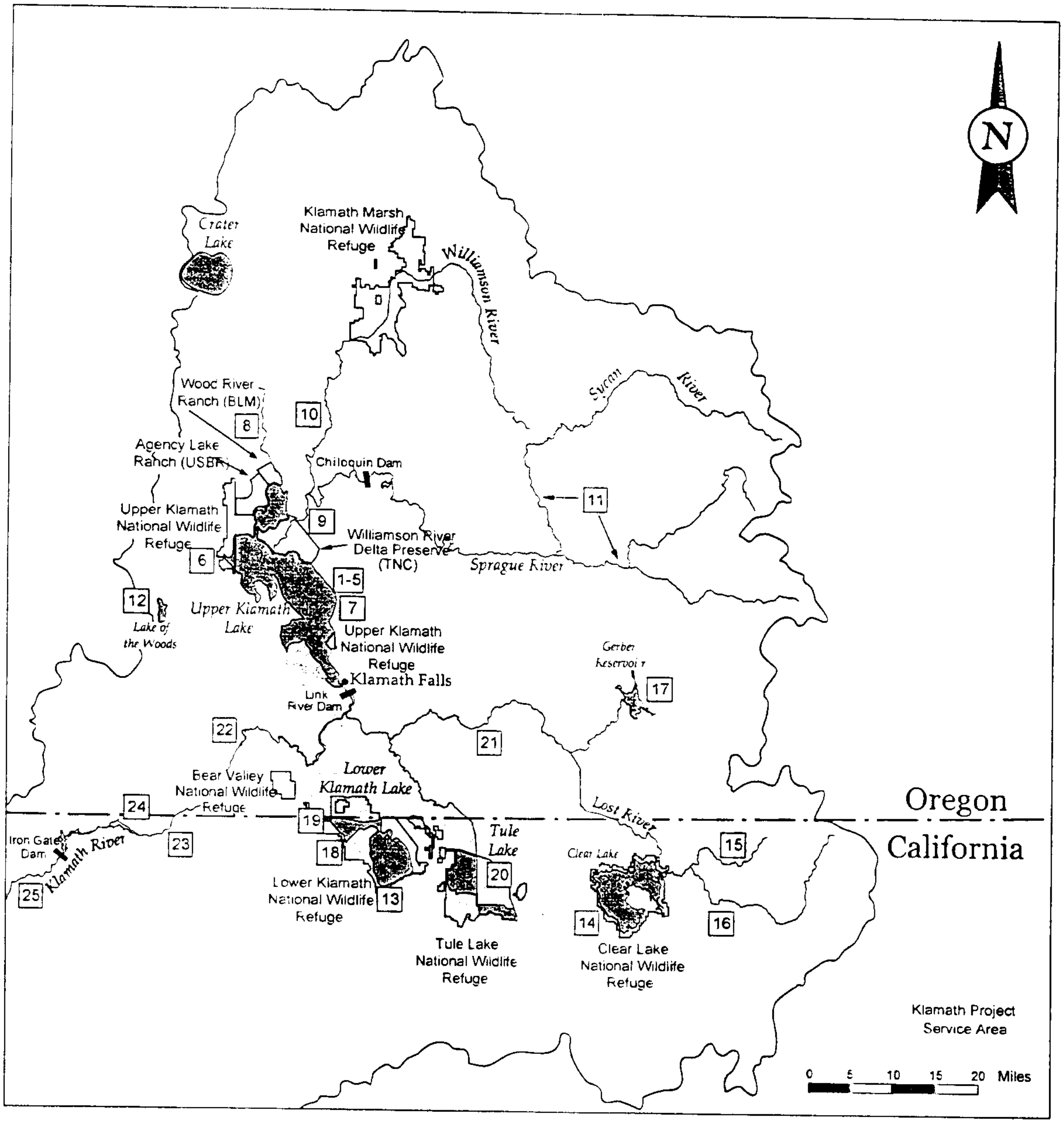


Figure 5-2. Locations of current and past populations of Lost River suckers and shortnose suckers. Numbers indicate current or former locations of suckers; light gray shows the area of the Klamath Project; dark gray shows standing water. See Table 5-3 for additional information.

Creek from Clear Lake and up the Sprague River to RM 74 from Upper Klamath Lake; R. S. Shively, U. S. Geological Survey, Klamath Falls, Oregon, personal communication, 2002). Upstream migrations commence when snowmelt leads to increases in river discharge—from early February through early April for Lost River suckers and from late February to late May for shortnose suckers (Moyle 2002). Spawning can occur at temperatures of 5.5-19°C (Moyle

Table 5-3. Current and Former Distribution of Adult Lost River Suckers and Shortnose Suckers in the Klamath Basin

Habitats[a]	Map Code	Lost River Suckers	Shortnose Suckers	Reference
Upper Klamath Lake		+	+	Moyle 2002
Peripheral Springs				
Boulder Springs	1	Spawn	Spawn	Hayes et al. 2002
Cinder Flats	2	Spawn	Spawn	Hayes et al. 2002
Ouxy Springs	3	Spawn	Spawn	Hayes et al. 2002
Silver Bldg. Springs	4	Spawn	Spawn	Hayes et al. 2002
Sucker Springs	5	Spawn	Spawn	Hayes et al. 2002
Harriman Springs	6	Spawn*	-	59 Fed. Reg. 61744 [1994]
Barkley Springs	7	Spawn*	-	59 Fed. Reg. 61744 [1994]
Tributaries				
Wood River	8	Spawn*[b]	Spawn	Markle and Simon 1994
Lower Williamson River	9	Spawn	Spawn	Cunningham et al. 2002
Upper Williamson River	10	0[b]	0	
Sprague and Sycan	11	Spawn	Spawn	Janney et al. 2002
Lake of the Woods, OR	12	0	+*[c]	Moyle 2002
Lower Klamath Lake, CA	13	+*	+*	Scoppettone and Vinyard 1991
Clear Lake, CA[d]	14	+	+[e]	59 Fed. Reg. 61744 [1994], USFWS 2002
Willow Creek	15	Spawn	Spawn	Moyle 2002
Boles Creek	16	Spawn	Spawn	Moyle 2002
Gerber Reservoir	17	0	+[e]	59 Fed. Reg. 61744 [1994]
Sheepy Lake	18	+*	+*	Moyle 2002
Sheepy Creek	19	Spawn*	-	Moyle 2002
Tule Lake	20	(+)	(+)	USFWS 2002
Lost River	21	Spawn[f]	Spawn	59 Fed. Reg. 61744 [1994]
J.C. Boyle Reservoir	22	(+)	(+)	53 Fed. Reg. 27130 [1988]
Copco Reservoir	23	(+)	(+)[g]	Scoppettone 1988, Scoppettone and Vinyard 1991
Iron Gate Reservoir	24	(+)	(+)	Moyle 2002
Klamath River	25	(+)	(+)	59 Fed. Reg. 61744 [1994]

[a]Tributary streams and springs are listed under lakes into which they flow.
[b]R. S. Shively, U. S. Geological Survey, Klamath Falls, Oregon, personal communication, 2002.
[c]An extirpated population of *Chasmistes* in Lake of the Woods, Oregon, originally referred to as *C. stomias* (Andreasen 1975), may have been another population of shortnose suckers (Moyle 2002).
[d]Drainage for Clear Lake includes numerous small reservoirs and tributary streams that contain both species (USFWS 2002, Appendix D).
[e]Shortnose suckers in Clear Lake and Gerber Reservoir may have been confused with Klamath largescale suckers or with shortnose suckers and Klamath largescale sucker hybrids (D. F. Markle, Oregon State University, personal communication 2002), although genetic information indicates that hybridization is rare (D. Buth, University of California at Los Angeles, and T. Dowling, Arizona State University, personal communications, July, 2002)
[f]Larvae in Lost River apparently do not survive (Moyle 2002).
[g]Shortnose suckers in Copco Reservoir may have hybridized with Klamath smallscale suckers (Scoppettone and Vinyard 1991).
Abbreviations: +, currently present; +*, previously present; (+), small population, probably nonbreeding; Spawn, current or previous spawning; Spawn*, spawning inferred from fish in spawning condition; 0, not known ever to occur; -, lack of information.

2002). For example, migrations of Lost River suckers up the Williamson River in 2001 were concentrated in April and May and showed a peak in mid-April. Spawning of shortnose suckers peaked in mid-May 2001 (Cunningham et al. 2002). In any given year, some temporal separation of spawning among species may occur. Klamath largescale suckers migrate first and are followed by Lost River suckers and then shortnose suckers (Coleman et al. 1988, cited in Scoppettone and Vinyard 1991), although migrations of the three may overlap (USGS 2002).

Shortnose suckers were numerically dominant in the lower Williamson River in 2001, but Lost River suckers outnumbered shortnose suckers by more than 10 to 1 at Chiloquin Dam, about 9 mi farther upstream (Cunningham et al. 2002, Janney et al. 2002). Thus, the Lost River suckers may be more likely than shortnose suckers to migrate upriver to spawn, or perhaps the two species react differently to dams. In 2001, 30 shortnose suckers were collected at lakeshore sites, compared to 900 found in the Williamson River, whereas Lost River suckers were five times more abundant at spawning sites in the lake than in the Williamson River system (Hayes et al. 2002, Cunningham et al. 2002). This suggests that spawning by shortnose suckers in Upper Klamath Lake is relatively rare at present. Shortnose suckers that do spawn in the lake use the same spawning sites as Lost River suckers. In flowing water, the suckers spawn in riffles or runs with moderate current (less than 3.3 ft/s) over cobble or gravel bottoms at depths of 0.7-6.6 ft (Scoppettone and Vinyard 1991, Perkins and Scoppettone 1996, Markle and Cooperman 2002). Gravel appears to be preferred; patches of gravel added to a spawning area will be used if flow and depth are appropriate (Golden 1969, Scoppettone and Vinyard 1991, Moyle 2002). Spawning in the upper Sprague River appears to be concentrated around springs (L. Dunsmoor, cited in USFWS 2002). Spawning behavior is similar to that of other suckers in that one female spawns with several males and the fertilized eggs, which are 2.5-3.2 mm in diameter, drop into spaces in the gravel.

Sampling at six known spawning sites along the eastern shoreline of Upper Klamath Lake (Sucker Springs, Silver Building Springs, Ouxy Springs, Boulder Springs, Cinder Flats, and Modoc Point) indicates that Lost River suckers spawning in the lake are slightly larger than those ascending the Williamson River (lake fish were 150-200 mm longer: Hayes et al. 2002, $p < 0.05$). Nearly 80% of the fish captured at lake spawning sites occurred at three of the six sites (Sucker Springs, Silver Building Springs, and Ouxy Springs). As is common among spawning suckers, males outnumber females at spawning sites. Sex ratios at nonspawning sites in Upper Klamath Lake indicate a predominance of females; males tend to remain at spawning sites, whereas females do not (Coen et al. 2002).

Lake spawning occurs in 0.5-3.7 ft of water; 95% of successful spawnings occur in water deeper than 1.0 ft, and about 35% occurs at 1-2 ft (Klamath Tribes, in USFWS 2002). Spawning aggregations were present from mid-March to early May. Peak abundances at all sites occurred during the first 2 wk of April, and a second peak occurred at Sucker Springs, the most heavily used site, in late April. The relative spawning condition (prespawn, ripe, postspawn) of fish captured in Upper Klamath Lake from February to June 2001 suggests that some eastern regions near spawning sites, such as Modoc Point and Goose Bay, are staging areas for spawning and that some western bays are used more heavily after spawning (Coen et al. 2002). The temporal sequence of capture of the sexes during the spawning season also suggests that males move to staging and spawning areas ahead of females.

Evidence from Hayes et al. (2002) is consistent with earlier conclusions by Perkins et al. (2000b) that river spawners and lake spawners constitute subpopulations of Lost River suckers in Upper Klamath Lake, but does not prove complete segregation of populations. Of 201 Lost River suckers tagged during previous years and recaptured at springs in the lake in 2001, with some recaptures separated by as much as three yr, 198 (98.5%) were captured both times at eastern shore spawning sites. The other three fish had been tagged in the Williamson River. Also, 76% of the fish recaptured at the Chiloquin Dam fish ladder in 2001 had been tagged originally at the ladder in previous years, and 20% of the fish had been tagged at other sites on the Williamson River (Janney et al. 2002). About half the Lost River suckers caught in Upper Klamath Lake were from sites other than those where they were tagged, either for within-year or between-year recaptures; this indicates that lake-spawning fish do not restrict their breeding activities to a single lacustrine spawning site. Ten shortnose suckers captured in 2001 were recaptures from previous years; all had originally been captured at shoreline sites. Movement between lake sites was apparent, as with the Lost River sucker.

Female Lost River suckers contain 44,000-236,000 eggs, and female shortnose suckers contain 18,000-72,000 eggs. Larger females bear more eggs, as is typical of most fishes (USFWS 2002). It is unknown whether individuals of either species spawn more than once each year or whether individuals spawn every year. Recapture data on lake spawners (Perkins et al. 2000b, Hayes et al. 2002) suggest that some Lost River suckers spawn every year. Cui-ui (*Chasmistes cujus*) are known to spawn several hundred times over a period of 3-5 days (Scoppettone and Vinyard 1991); Lost River suckers and shortnose suckers might behave similarly. Coen et al. (2002) found that 75% of male but only 40% of female Lost River suckers and 69% of male but only 46% of female shortnose suckers captured in February-June 2001 were in spawning condition (see also Coen and Shively 2001). These observations suggest that a large portion of the adult population of both species is not in spawning condition during any given spawning season. Observations of tagged fish frequenting more than one lake spawning site in a year suggest multiple spawning events for individual fish. Frequency of spawning is relevant to the populations' potential for recovery.

Larvae

Embryos remain in the gravel for 2-3 wk (USFWS 2002). The subsequent larval stage lasts for about 40-50 days (Markle and Cooperman 2002). Stream-spawned larvae emerge ("swim up") from the gravel and immediately move downstream, mostly at night, in late March to early June, depending on spawning date (Moyle 2002). The abundance of larvae peaked in the Williamson River system 21 days after the peak in spawning (Coleman et al. 1988, cited in Scoppettone and Vinyard 1991). Larvae spawned in the Williamson River system pass to Upper Klamath Lake in as little as a day. More than 99% of larvae enter the lake before the caudal fin has formed and well before the yolk sac is absorbed, after which the fish must feed (Cooperman and Markle 2000). How these movement rates are related to location of spawning (lower Williamson River or Sprague River below or above Chiloquin Dam) and how different they would be if more fish spawned above the dam are unknown. Larval mortality in the Williamson

River is around 93% per day (L. Dunsmoor, personal communication, in Markle and Cooperman 2002). Mortality in fishes with planktonic larvae is in general very high (Houde 1987, 1997).

Larval habitat is best described as shallow, nearshore, and vegetated in both rivers and lakes (Figure 5-3) except in Clear Lake and Gerber Reservoir, which lack vegetation (Klamath Tribe 1991, Markle and Simon 1994, Reiser et al. 2001). Larvae are most abundant in the northeastern portion of Upper Klamath Lake, including the Williamson River estuary and the lower Williamson River (Markle and Cooperman 2002). In Upper Klamath Lake, larvae first concentrate near emergent vegetation at the mouth of the Williamson River for several weeks and then appear in other regions of the lake where emergent vegetation is found; that this process can continue for more than 2 mo is not surprising, given the protracted spawning period of the suckers (Cooperman and Markle 2000).

Studies of the larval use of habitat have focused on the importance of depth and vegetation as components of habitat. Observations by Coleman et al. (1988), Buettner and Scoppettone (1990), the Klamath Tribes (Klamath Tribe 1991; Klamath Tribe, Natural Resources Department, Chiloquin, Oregon, unpublished material, 1996), Cooperman and Markle (2000), and Reiser et al. (2001) indicate use of shallow water (less than 4.3 ft and often less than 20 in) sometimes in areas devoid of cover but more usually near emergent vegetation, such as bullrush beds. Larvae use emergent vegetation primarily from early May through late June, although larvae may be found up to mid-July (see Reiser et al. 2001) because spawning continues into late May. Submerged aquatic vascular plants apparently are less important than emergent vegetation (Cooperman 2002), probably because macrophyte beds are seldom well developed in spring, when much of larval growth occurs. Larvae may not necessarily aggregate within dense vegetation itself but rather near it or in openings in the vegetation in areas described as "pockets of open water surrounded by emergent vegetation," or "the open water/emergent vegetation interface" (Reiser et al. 2001, p. 4-9).

Successful spawning and recruitment of suckers in Clear Lake, which is largely devoid of emergent and submerged vegetation, show that larvae can survive without such vegetation. Clear Lake is very turbid, however, and this may provide protection from visual predators. Laboratory tests show that predation on larvae by fathead minnows is highest when larvae lack cover (Dunsmoor 1993). Young and small fishes in fresh-water and marine habitats worldwide often take refuge in dense vegetation when threatened by predators, although larvae of some species are entirely pelagic.

Clear Lake contains flooded annual grasses and herbs and emergent and submerged vegetation in tributaries that may be used by larvae, and it has fewer introduced predators, such as yellow perch and fathead minnows, than does Upper Klamath Lake (USFWS 2002). Thus, successful recruitment in Clear Lake does not demonstrate that vegetation is unimportant in Upper Klamath Lake. Successful spawning apparently does not occur in any of the mainstem reservoirs, which have steep shorelines, lack substantial emergent vegetation, have abundant predators, and may lack spawning areas (Desjardins and Markle 2000).

Juveniles (1-4 Inches)

Larvae are considered juveniles at a length of 1-4 in, which the suckers generally achieve

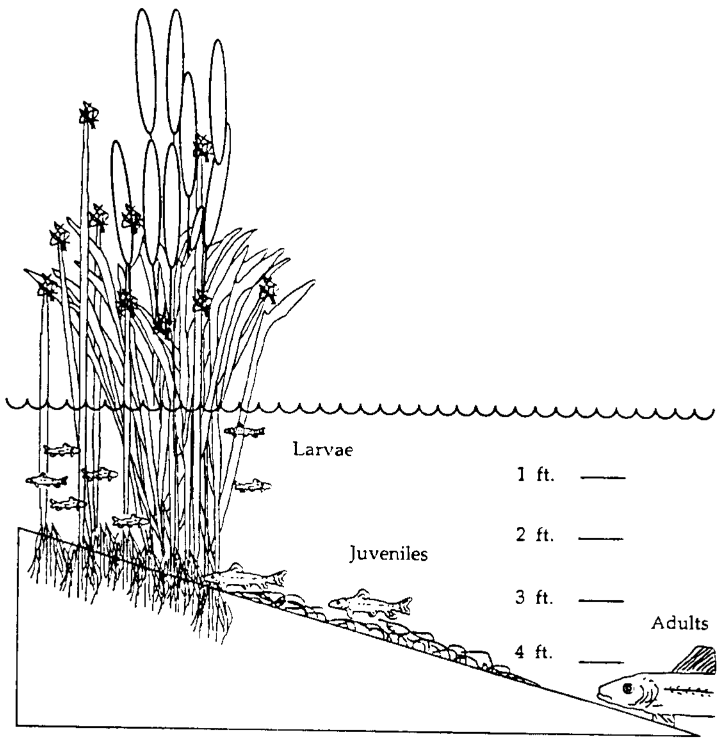


Figure 5-3. Generalized view of habitat of young suckers in Upper Klamath Lake. Source: USFWS 2002, p. 83.

by the end of July (USFWS 2002). Juveniles are termed young of the year (YOY) or age 0 through their first winter. They spend daytime near shorelines over clean, rocky bottoms composed of sand, gravel, and small boulders (Simon et al. 2000; Figure 5-3). YOY use both vegetated and unvegetated portions of shoreline, generally in water less than 4.3 ft deep (USFWS 2002). Knowledge of the extent to which vegetation is used is complicated by the difficulties of sampling juveniles in dense vegetation (Reiser et al. 2001). Abundance of YOY at first is greatest in the northeastern portion of Upper Klamath Lake; as summer progresses, young fish move southward in the lake and into deeper water and become less associated with shorelines, and they become more oriented toward the lake bottom (Gutermuth et al. 2000). Simon and Markle (2001) suggest that overwinter mortality of first-year juveniles approaches 90%. After their first year, juveniles are found throughout the lake but are most abundant in the northern one-third of the lake, as are adults, although it may be important that sampling has been concentrated on this area (Reiser et al. 2001). Juvenile Lost River suckers appear to depend less on shallow-water habitats than juvenile shortnose suckers, as shown by sampling with beach seines (Simon et al. 2000), and juvenile shortnose suckers are apparently more strongly oriented toward the lake bottom than juvenile Lost River suckers (Scoppettone et al. 1995).

Subadults (4 -10 Inches) and Adults

Subadults are the least-studied age group. It is assumed that their requirements and habits are most like those of nonspawning adults but their behavior is obscure because they are too fast to catch in seines or trawls, too deep to catch in cast nets, and often too small to gillnet. Given that suckers may spend the first 3-8 yr of their lives as subadults, additional information on this stage could be important.

Lost River suckers grow rapidly for their first 5 or 6 yr to a length of 14-20 in (Scoppettone 1988). Some males reach maturity (i.e., are capable of spawning) at 4+ yr and 15 in and some females do so at 7+ yr and 21 in, but most fish mature at 8 or 9 yr; males often mature earlier than females. At maturity, growth slows (Scoppettone 1988, Buettner and Scoppettone 1990, Scoppettone et al. 1995, Perkins et al. 2000a). The largest and oldest fish are females. The oldest known Lost River sucker (43 yr) was obtained in Upper Klamath Lake during a fish kill in 1986 (Scoppettone 1988).

Female shortnose suckers apparently grow faster and larger than males. Both male and female shortnose suckers mature as early as 4+ yr. Males can be mature at 11 in and females at 13 in, although maturation at 5-7 yr is more usual. The oldest known shortnose sucker (33 yr) was taken from Copco Reservoir in 1987 and was 19 in long (Scoppettone 1988).

Adult Lost River suckers forage primarily on zooplankton and benthic (bottom-dwelling) macroinvertebrates (Coleman et al. 1988, Scoppettone and Vinyard 1991). The shortnose sucker, as could be predicted from the more terminal position of its mouth, feeds predominantly on cladoceran zooplankters (water fleas), although the guts of only a few adults have been examined (Coleman et al. 1988). The presence of detritus in the guts of shortnose suckers from Clear Lake indicates that shortnose suckers may also feed close to the bottom (Moyle 2002).

Adult suckers select water depths of 3-15 ft, as shown by daylight spring and summer observations; their strongest preference appears to be for 5-11 ft (Reiser et al. 2001, USFWS 2002). Their minimal use (1% of daytime observations) of shallower water could reflect avoidance of high light intensities and thus of aerial predators; limited use of the deepest water (about 4% of daytime observations), particularly in summer, may reflect avoidance of low concentrations of dissolved oxygen (Chapter 3).

Although adults of the Lost River suckers and shortnose suckers are captured together in many places in Upper Klamath Lake, some differences in their distribution suggest different habitat preferences. For example, in 2001, Lost River suckers were 2-3 times more abundant in trammel net samples from the western shoreline of Upper Klamath Lake, whereas shortnose suckers were 2-3 times more abundant in samples from the eastern shore (Coen et al. 2002). Possible habitat differences in these regions might be worthy of further investigation, although the differences could reflect chance encounters with aggregations of the two species.

Physiological Tolerances

Lake suckers in general are relatively tolerant of water-quality conditions that are unfavorable or even lethal for many other fishes. For example, suckers in good condition occur in Tule Lake, which periodically experiences extremes of dissolved oxygen, pH, and ammonia that are toxic to fathead minnows, a tolerant species (Dileanis et al. 1996, cited in USFWS 2002). Other lake sucker species are similarly tolerant. Endangered cui-ui evolved in the very alkaline (pH, 9.0-9.5) and saline (5 ppt) waters of Pyramid Lake, Nevada, where only five or six other native fish species persist. The only nonindigenous fish species to have successfully colonized Pyramid Lake is the Sacramento perch (G. G. Scoppettone, U. S. Geological Survey, Reno, Nevada, personal communication, 2002).

Most fishes cannot tolerate sustained pH in excess of 9 (Falter and Cech 1991). Upper Klamath Lake suckers can tolerate pH approaching 10, temperatures up to 31-33°C, concentrations of unionized ammonia up to 0.4-0.5 mg/L, and dissolved oxygen concentrations down to 1.5 mg/L. Beyond these thresholds, the suckers die in laboratory tests (typically conducted on juvenile fish); larvae are more sensitive than larger fish (Falter and Cech 1991, Martin and Saiki 1999, Saiki et al. 1999, Moyle 2002). Mortality is high in adult suckers below oxygen concentrations of about 1 mg/L (Chapter 6). Falter and Cech (1991) found that shortnose suckers had much lower tolerance of high pH (measured as pH at which swimming equilibrium was lost) than two other endemic fishes, the Klamath tui chub and the Klamath largescale sucker. Shortnose suckers lost equilibrium at a mean pH of 9.55, tui chub at 10.75, and Klamath largescale suckers at 10.73. Maximum pH in Upper Klamath Lake during summer phytoplankton blooms frequently exceeds 9.5 at the surface during daylight hours, but pH during episodes of mass mortality generally is about 7.5-8.5 (Perkins et al. 2000b), indicating that high pH does not cause mass mortality (Chapter 3). In Upper Klamath Lake in late summer, during times of physiological stress, suckers may seek higher water quality, such as that of springs and river mouths, even though such areas are otherwise avoided, probably because they are too shallow or too clear (USFWS 2002, Appendix D; Chapter 6).

Physiological tolerance tests generally are performed in a laboratory on single factors held at constant values, whereas factors in nature often vary over time and space, co-occur, and can operate synergistically. Summer conditions in Upper Klamath Lake typically involve episodes of high pH, high unionized ammonia, and low dissolved oxygen in combination with high temperatures that increase the oxygen demand of the fish. High concentrations of unionized ammonia can cause structural damage to gills, which can increase the susceptibility of fish to low concentrations of dissolved oxygen. High pH (over 9) inhibits ammonia excretion, thus creating stress (Lease 2000, cited in USFWS 2002). Susceptibility to columnaris disease, which is caused by the bacterium *Flavobacterium columnare*, increases with increasing temperature but decreases with increasing ammonia concentrations (Morris et al. 2000, Snyder-Conn et al. unpublished in USFWS 2002).

As an adjunct to laboratory studies, Martin and Saiki (1999) placed cages containing juvenile Lost River suckers in Upper Klamath Lake for 4-day periods. High mortality occurred at high pH, high concentrations of unionized ammonia, and low concentrations of dissolved oxygen; low dissolved oxygen was the strongest correlate with mortality. At sublethal temperatures and concentrations of unionized ammonia, fish were tolerant of higher pH than expected from the laboratory studies (fish tolerated pH as high as 10.8). The study suggests that laboratory tests of single factors should be viewed as being only indicative of the extremes that can be tolerated; they are not strictly predictive of responses in the field.

From the viewpoint of physiological stress on fishes generally, and especially for coldwater fishes, water-quality conditions are poor throughout much of the Klamath basin, as explained in Chapters 3 and 4. Physiological thresholds for suckers, however, are reached or exceeded less extensively than for most fishes because of the high tolerance of suckers. Harm to suckers caused by poor water quality is known for Upper Klamath Lake and may also occur in the Lost River and upper Keno Reservoir (Lake Ewauna). In other lacustrine or flowing-water environments of the basin, however, poor water quality may be much less important than other factors for suckers, although it may strongly affect some other fishes.

In Upper Klamath Lake, suckers are adversely affected by poor water quality, which is a byproduct of very high abundances of *Aphanizomenon flos-aquae*, a planktonic bluegreen (cyanobacterial) alga. Peak abundances of *Aphanizomenon* occurring in late summer or early fall cause very high pH. Under certain meteorological conditions overturn of a stratified water column and collapse of the *Aphanizomenon* population combine to cause depletion of oxygen throughout the water column and distribution of high concentrations of unionized ammonia (Chapter 3).

The adverse water-quality conditions in Upper Klamath Lake potentially have three types of effects on endangered suckers in Upper Klamath Lake: (1) mass mortality of large fish, (2) mortality, either episodic or continuous, of small fish or larvae, and (3) physiological stress on one or more age classes, which leads to physiological impairment but not necessarily death.

Poor water quality in Upper Klamath Lake is a documented cause of the episodic mass mortality of large suckers in the lake. The recent history of these episodes is given in this chapter, and the factors producing death are discussed in Chapter 3. Extensive research on the direct cause of mortality during episodes of mass mortality has led to the reasonably firm conclusion, supported by scientific evidence, that mortality is caused by inadequate amounts of dissolved oxygen. The two other potential direct causes of mortality, pH and unionized ammonia, appear not to control mass mortality. Dissolved oxygen, unlike pH and unionized ammonia, remains adverse continuously for many days during episodes of mass mortality, whereas pH and unionized ammonia do not. Thus, although additional studies of mechanisms leading up to mass mortality are warranted, the direct cause in large fish seems to be understood reasonably well.

There is insufficient evidence to show whether extreme water-quality conditions also cause mortality of juveniles and larvae. Laboratory experiments indicate such potential, but it has not been documented in the field. Field documentation, especially if mortality were steady rather than episodic, would be difficult for the smaller life stages of fish because of their quick deterioration and dispersal after death. The possibility that gradual or episodic mass mortality of small fish occurs should be studied.

Adverse water-quality conditions can affect fish indirectly, as explained above. Laboratory studies are useful, but field indicators of stress also are important in that sublethal responses to stress cannot always be produced in an interpretable way in the laboratory. Indicators of physiological stress include unusual or recurrent epizootics, poor body-condition factors, physical anomalies, and low growth rates compared with those in populations that are not exposed to adverse water-quality conditions, abnormally low fecundity or fertility of mature fish, and behavioral aberrations. Some attention has been given to the indicators—for example, physical anomalies in suckers of Upper Klamath Lake are common (USFWS 2002)—but a more comprehensive effort at evaluating indicators of stress probably is warranted.

Overall, there is no doubt that poor water-quality conditions are suppressing the endangered suckers of Upper Klamath Lake through mass mortality of large fish. Less clear is the role of potential additional suppression through mortality of smaller fish or sublethal effects of physiological stress caused by poor water-quality conditions on any or all life stages.

Population Size

Abundances of larval and juvenile suckers have been estimated from field samples over the last several years (e.g., Simon et al. 2000). Calculated population sizes of adults have been based on recapture of tagged fish during fish kills. The confidence intervals around the numbers are very large and, because many of the assumptions of mark and recapture methods are not met by these estimates, the estimates are of limited value (R. S. Shively, USGS, unpublished memo, 5 March 2002; USFWS 2002).

Newspaper reports, eyewitness accounts, and data on catch per unit effort leave little doubt that the sucker population exploited by the snag fishery in the 1960s and earlier was much larger than it was by the 1980s. Relative estimates of the size of the spawning run of suckers in the Williamson River were first based on estimated catch rates and later on standardized recapture and electrofishing methods. The estimates showed a marked decrease in abundance of fish during the middle 1980s. In 1984, the run of spawning Lost River suckers was estimated at 23,000, but it fell to 12,000 in 1985. Catch per unit effort of electrofishing fell by 57% for Lost River suckers and by 83% for shortnose suckers from 1984 to 1986 before the major fish kill of 1986 (Scoppettone 1986, Bienz and Ziller 1987, Scoppettone and Vinyard 1991). The fishery was closed in 1987. More recent estimates of abundance depend on catch per unit effort in standardized trammel-net samples and can be compared only among collections for the years 1995-2001.

No universal or absolute estimates of the size of any age class of sucker are available. Estimates are relative, limited to specific sites (e.g., spawning areas), or are otherwise qualified from the viewpoint of making an overall numerical assessment of the population. While the use of qualified or relative estimates is beneficial, efforts to make more comprehensive population size estimates in the future would be desirable (see Chapter 6). For purposes of ESA actions, the critical facts, which are known with a high degree of certainty, are that the fish are much less abundant than they originally were and that they are not showing an increase in overall abundance. Thus, the point of departure for research and remediation in the future is the need to restore abundance of the listed suckers.

Age-Class Structure

Most adult fish in Upper Klamath Lake are large and old. The uneven age distribution has characterized the populations for several decades. Through the 1980s, the age distribution of Lost River suckers was heavily skewed to fish 19-28 yr old. In 1986, the year before fishing was banned, recruitment had apparently been poor for about 18 yr; 95% of adult Lost River suckers were 19-30 yr old (Figure 5-4; Scoppettone 1988). The data for Lost River suckers shown in Figure 5-4 are based on fish obtained during fish kills, a sampling method with unknown but multiple biases, including some evidence that older, larger fish suffer disproportionately high mortality (Chapter 6). Assuming that the fish collected during fish kills are representative of the adult population as a whole, it can be concluded that many age classes were essentially missing from the lake before 1988, when the fishery was active.

Closure of the fishery in 1987 greatly reduced mortality of spawners, after which additional mature fish began entering the spawning population (Figure 5-4B). Cessation of fishing apparently contributed to the production of a strong year class of both endangered sucker species in 1991, and to smaller but notable year classes also produced in 1990, 1992, and 1993 (Figure 5-4B; see Markle and Simon 1994, Cunningham and Shively 2001). These fish would have been expected to mature in the late 1990s, but the major fish kills that occurred in 1995, 1996, and 1997 affected not only old spawners but also probably young spawners. Spawning runs declined in the late 1990s, with little evidence of substantial recovery until 2000 (Figure 5-5). The upsurge in spawning numbers in that year and again in 2001 may represent maturation of fish from the 1991 and later year classes. It is possible that fish that lived through the fish kills of the middle 1990s were stressed by poor water quality and as a result experienced delayed maturation (e. g., Trippel 1995, Baltz et al. 1998), although Terwilliger et al. (M.R. Terwilliger et al., Oregon State University, Corvallis, OR, unpublished material, 2000) found no evidence of impaired growth associated with periods of poor water quality in juvenile suckers of Upper Klamath Lake. That spawning runs apparently increased in 1999-2001 shows that the species have substantial resilience, but this is no guarantee of recovery.

Comparisons between 2000 and 2001 data indicate a weak but significant trend toward increasing average size among all spawning shortnose suckers and female Lost River suckers in the Williamson River (Cunningham et al. 2002). A similar significant trend toward increased median size at a variety of nonspawning sites in Upper Klamath Lake was also found (Coen et al. 2002). When combined with evidence of low numbers of small river-spawning fish in recent years (Cunningham et al. 2002), the data could indicate year-class failure among fish that hatched in the middle 1990s and that would mature in the early 2000s. Concern over lost year classes might be tempered by an apparent trend in increased overall abundance among river spawners in 1999-2001 (Figure 5-5). Catches of both species from the Williamson River in spring 2002 decreased, however, by about 50% compared with 2001 (R. S. Shively, U. S. Geological Survey, Klamath Falls, Oregon, personal communication, October 8, 2002). Abundance index (catch per unit effort) for lake-spawning Lost River suckers do not indicate an increase in numbers of spawners (1999, 3.0 fish/h; 2000, 2.0 fish/h; 2001, 2.4 fish/h), and the average size of lake-spawning fish increased significantly between 2000 and 2001, suggesting lack of recent recruitment into the spawning population (Hayes et al. 2002). Catches at the shoreline areas in 2002 also decreased by about 15-20%. In fact, sampling in 2002 indicates that there has been no substantial recruitment into the adult population since 1999 (R. S. Shively, U. S. Geological Survey, Klamath Falls, Oregon, personal communication, October 8, 2002).

Observations on size of spawners since 1984 (Perkins et al. 2000b) indicates that very large Lost River suckers (over 25 in for males, and over 28 in for females) have been lost progressively from the population, that recent spawning aggregations are made up largely of medium-size fish (18-24 in), and that the median age of spawners for Lost River suckers is 12 yr and for shortnose suckers is 9 yr (as judged from age-length relationships; Markle and Cooperman 2002). These findings suggest that successful year classes after 1991-1993 are largely absent, that is, that little recruitment of young spawners has occurred at the same time that the largest fish have been progressively removed by the fish kills; this raises a concern over future numbers of spawners and total reproductive output of the population.

As with Lost River suckers, knowledge of age distributions of shortnose suckers in Upper Klamath Lake comes chiefly from three fish kills in the 1990s, except that the data are even less complete and earlier data are lacking (Figure 5-4B). Indications from age distributions of fish collected after fish kills have indications similar to those for the Lost River suckers.

One other trend of note is that larger fish appear to spawn earlier in the season (Perkins et al. 2000b), but this trend may have been obscured in recent years by a relative lack of small spawners (Hayes et al. 2002). Regardless of cause, multiple strong year classes with temporal separation in spawning between year classes is potentially advantageous because it decreases the likelihood of failure of all the year's larvae if environmental factors vary for year to year during the breeding season (e.g., Trippel 1995).

Information on age distribution is a fundamental indicator of the status of a population, and it sometimes suggests reasons for failure of a species to recover. Although the 1990s, in apparent contrast with earlier years when the fishery was in place, have produced recruitment into the subadult and adult stages, the fish entering these stages have been killed in large numbers during episodes of mass mortality in Upper Klamath Lake. Thus, one reason for failure of the populations to recover is probably suppression of reproductive capacity of the population due to selective mortality of adult fish. This does not, however, rule out the possibility that part of the explanation for lack of recovery lies in suppression of the number of fish entering the subadult and adult phases. The fish collected during fish kills indicate recruitment into the subadult and adult stages in all years, and especially in some years with notably abundant year classes (such as 1991), but the amount of this recruitment may be insufficient to support overall growth of the population. Thus, one bottleneck almost certainly involves the mass mortality of large fish, and a second bottleneck could be at one or more places in the life cycle between laying of eggs and the entry of fish into the subadult and adult categories. As cited above, numerous efforts are under way to identify unusual mortality or suppression of vigor in young fish, but no conclusions are yet available on this important matter.

Perspective on Age-Class Structure and Strength, Mortality, and Reproductive Output

Most fishes experience astronomically high mortality in their early life-history stages. The millions or even billions of individuals that hatch in a population are reduced by many orders of magnitude at the time of maturation. On the average, a male and female just replace themselves over a lifetime of spawning, even though they may produce millions of fertile eggs. These facts are relevant to sucker recovery in several ways. High mortality among larvae and small juveniles is to be expected, but the rates should plummet in later years, and old fish should show low mortality. Small percentage changes in mortality of young fish can translate into large

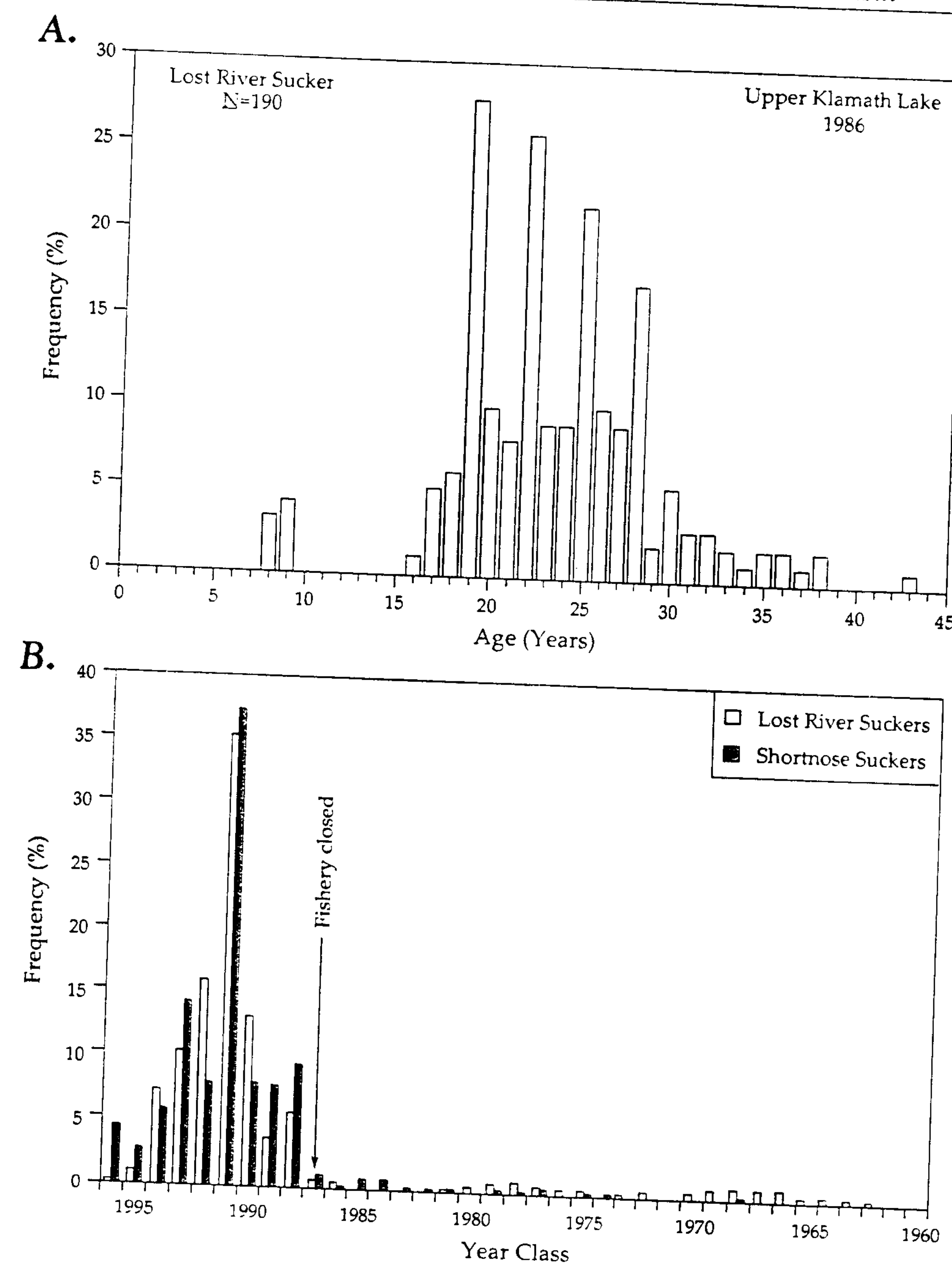


Figure 5-4. Age distributions of suckers in Upper Klamath Lake based on fish kills. (A) Age distribution of Lost River suckers in Upper Klamath Lake based on the 1986 fish kill. Multiple peaks indicate strong year classes estimated as 1958, 1961, 1964, 1967 Source: Scoppettone and Vinyard 1991; (B) Age frequency distributions of Lost River suckers and shortnose suckers in Upper Klamath Lake based on fish collected from the 1997 fish kill. Effects of fishery closure in 1987 and of entry of successful 1991 year class are evident. Fish as old as 35 yr (spawned in 1962) were present. Source: Markle and Cooperman 2002, based on data from R. Shively, USGS.

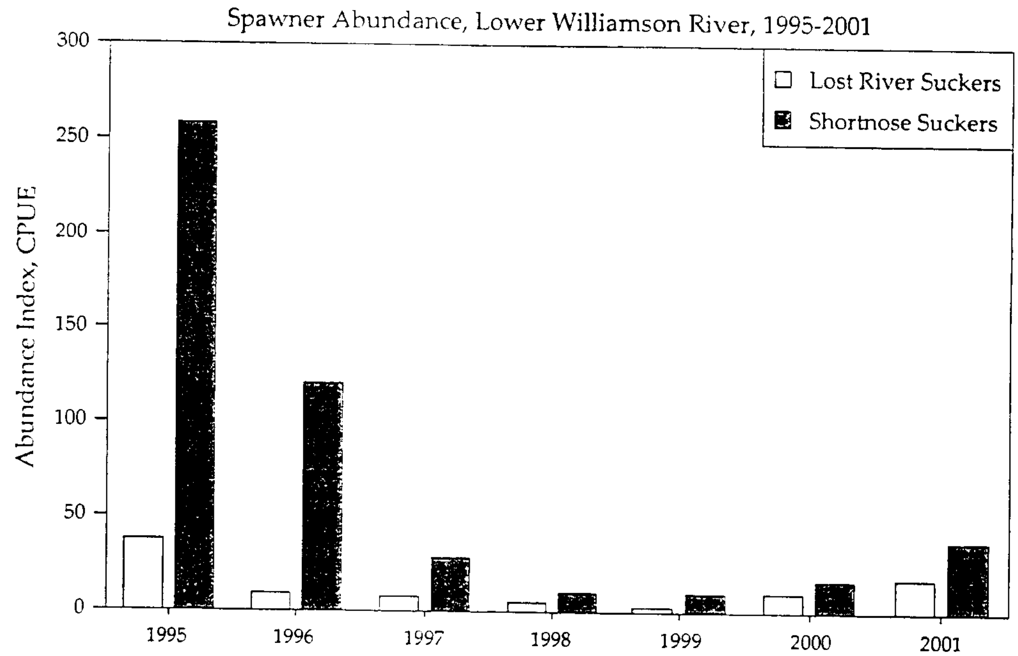


Figure 5-5. Spawning-run abundances of lake suckers, lower Williamson River, 1995-2001. Decline in spawners consistent with expected changes given fish kills of 1995-1997 is evident (1995 data were obtained before the fish kill that year). CPUE is a measure of catch per unit effort based on fish caught per unit of time spent fishing with trammel nets. Source: modified from Cunningham et al. 2002, p. 30.

population differences later because of the high numbers of young individuals. Thus, any steps that can be taken to increase larval and juvenile survival in Klamath Lake suckers could produce great benefits.

The high mortality experienced by very old fish during the fish kills of the middle 1990s is especially alarming given the reproductive potential of these fish (e.g., Conover and Munch 2002). Large, old fish of most species produce disproportionately more eggs than smaller fish. For example, in red snapper (*Lutjanus campechanus*), which is heavily fished and depleted throughout its North American range, a single 10-yr old female (26 lb, 24 in) can contain 9 million eggs, which is equivalent to the total egg output of 212 adult females that are 3-4 yr old, weigh 2.2 lb each, and are 17 in long. One 26 lb old fish produces more eggs than 250 lb of younger fish. Thus, loss of larger size classes in a population can have a disproportionate effect on egg production and future recruitment (Bohnsack 1994). The value of large fish, even in small numbers, is evident in the listed suckers. The number of young produced and eventually recruited into adulthood increased greatly just after the snag fishery was closed (see Figure 5-4B), demonstrating that even low numbers of large fish can produce large numbers of recruits (Markle and Cooperman 2002).

The disproportionately high contribution of old fish is even greater than fecundity would indicate. Because the quality of eggs (size and amount of yolk) produced by old females may be greatest, larvae hatching from these eggs may be larger and more likely to survive the early periods of high mortality (e.g., Trippel 1995). Although numbers of spawning fish in the Williamson River appear to have climbed in recent years, the reproductive potential of the population is lower than it was before the fish kills because the fish are smaller (Markle and Cooperman 2002). Reproductive output of a population is determined jointly by the number of spawners and the age distribution of spawners. Two populations of equal size that contain different size distributions of fish will not be equal in reproductive value; the population with more old, large fish will have much higher reproductive potential. Any alterations that can be made in the environmental conditions that directly affect the probability or severity of fish kills should receive especially careful consideration (Chapter 3).

Species that are long lived and late to mature, such as the endangered suckers of the Klamath basin, may respond slowly both to degradation and to restoration of habitat requirements, in contrast to other species that mature more quickly. Thus, the presence of old fish is not in itself evidence of a sound population. In fact, even if old fish are numerous, their failure to propagate would render them implicitly extinct until a reversal of the situation occurs. Similarly, improvement of environmental conditions may lead to beneficial changes in the population through recruitment of young age classes, but the final evidence of progress toward recovery, which is survival of these younger classes to maturity and old age, will not be evident for a decade or more. This special perspective on the long lived, slow maturing suckers must be maintained in any evaluation of prospects for extinction and response to remediation.

Endangered Suckers in Other Klamath Basin Waters

Suckers occurred naturally in Tule Lake, Sheepy Lake, and Lower Klamath Lake, from which spawning fish ran up the Lost River (Table 5-3). All three of the lake populations apparently were extirpated when their waters were drained for agricultural purposes around 1920 (Chapter 2). During the 1930s, after farming failed in the former lake bed, the lakes were to some extent reinundated, but not to their former depths. Suckers recolonized Tule Lake but not the other two lakes. There has been no evidence of successful spawning in Tule Lake, although fish from the lake evidently spawn in the lower Lost River.

Fish of both species, but mostly shortnose suckers, have been found regularly in the reservoirs between Keno and Iron Gate Dam (e. g., J. C. Boyle, Copco, Iron Gate). Apparently, they do not spawn. Fish in these impoundments probably consist of individuals that enter the Link River from Upper Klamath Lake and survive passage at Link River Dam; they tend to be old and large (Figure 5-6). The trip out of Upper Klamath Lake is one-way, in as much as no fish ladders suitable for suckers are located at Link River Dam or at any of the other dams along the Klamath River (Chapter 6). The great size and age of female fish as suggested by Figure 5-6 could make such fish valuable as transplants to more favorable habitats.

Reproducing populations of endangered suckers exist in Clear Lake, in Gerber Reservoir, and in portions of the Lost River downstream (the Lost River could receive fish from Gerber Reservoir in its upper portion and from Tule Lake in its lower 7 mi, below Anderson Rose Dam). Clear Lake, which was established in 1910, contains populations of both species (Scoppettone et al. 1995 estimated that 73,000 suckers occupied the lake), and both show recent evidence of

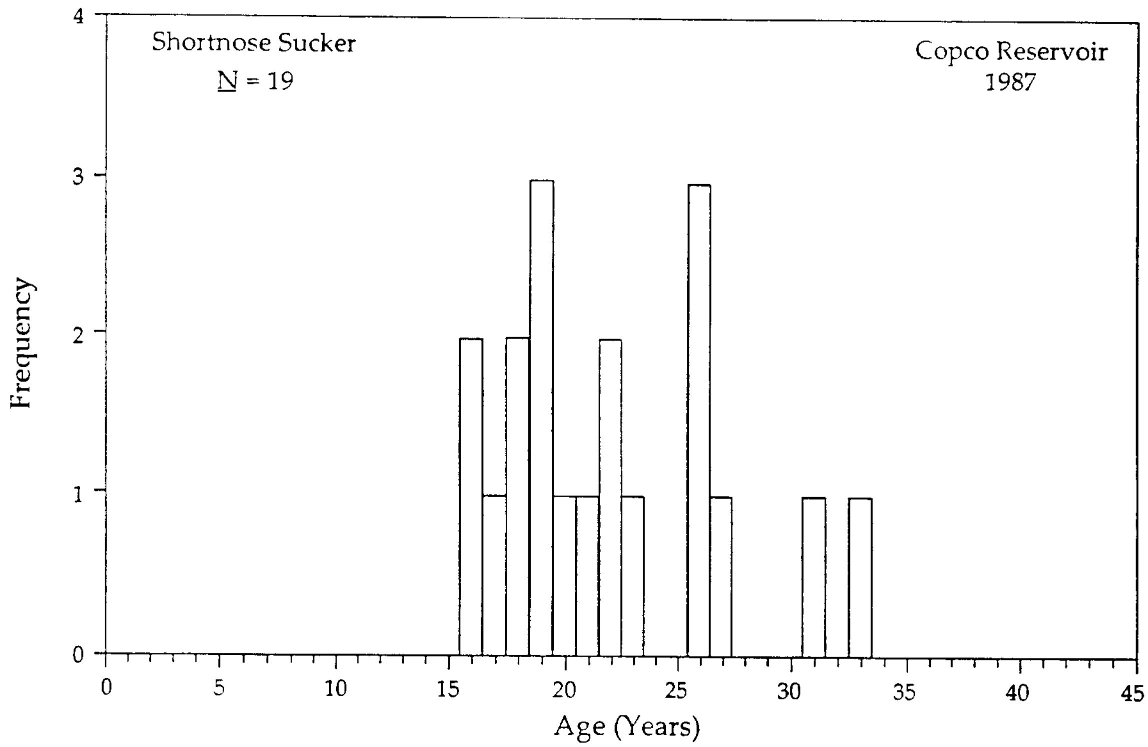


Figure 5-6. Age structure of a small sample of shortnose suckers taken from Copco Reservoir, 1987. Source: Scoppettone and Vinyard 1991, permission pending.

diverse age structure and continued successful reproduction and recruitment. The reservoir is a source of irrigation water and can be drawn down during drought, which exposes the fish to multiple threats. Clear Lake was drawn down to as low as 5% of capacity during 1992, and fish collected after the drawdown and in the next spring were in poor condition, although their condition rebounded by the end of the next summer (USFWS 2002). Success of shortnose suckers and Lost River suckers in Clear Lake is encouraging in its own right and as a potential rescue population that could be used for restoring populations in other water bodies. Extreme drawdown, although prohibited by the USFWS biological opinion of 2002, is a threat if it should occur inadvertently, and the lake and its suckers presumably are vulnerable to major environmental disasters, such as a break in the dam (Moyle 2002). Unexpected changes in the spawning and rearing habitats in Willow and Boles Creeks above the reservoir also could affect sucker abundances.

Gerber Reservoir, which was created in 1925, contains shortnose suckers but not Lost River suckers. Shortnose suckers in Gerber Reservoir exhibit a wide range of size classes, indicating successful reproduction and recruitment. Gerber Reservoir is not connected to any other sucker population, so there is no possibility of genetic exchange. Condition of fish in Gerber Reservoir is known to vary from poor to good; poor condition was associated with lowest water levels in 1992 (the lake was drawn down to 1% of capacity). The population has not received a great deal of attention.

Gerber Reservoir flows into the Lost River, which flows into Tule Lake (Figure 1-2). Historical sucker runs out of Tule Lake and up the Lost River were substantial; these runs supported commercial fisheries and canneries (USFWS 2002). Today, after the construction of multiple dams, only small numbers of the two endangered species occur in the Lost River; shortnose suckers are more common than Lost River suckers. It is not known whether these populations are self-sustaining (USFWS 2002). Spawning habitat is limited, and spawning has been observed at only about three locations, although several other sites appear to provide appropriate spawning habitat. Small numbers of larvae and juveniles have been collected in the river, but these fish could originate in Gerber Reservoir. Upstream movement from Tule Lake ends at Anderson Rose Dam, 7 mi above the lake. Spawning habitat in the 7-mi reach is scarce, and rearing habitat is compromised by poor water quality from water connected with Tule Lake sumps and agricultural return flows. Water quality in the Lost River is generally poor; the river fails to meet several Oregon state-specified water-quality thresholds. Gradients in portions of the river are unfavorably steep for suckers, and seasonal dewatering is common, as are dense plant growth and algal blooms associated with poor water quality. Both summer and winter fish kills were documented for the Lost River Diversion Canal region in the late 1990s. Brown bullhead (*Ameiurus nebulosus*) and pumpkinseed (*Lepomis gibbosus*) are abundant and nine of the 16 fishes in the river are warmwater nonnatives. USFWS (2002, Appendix E, p. 31) concludes that the Lost River is highly degraded and “can perhaps be best characterized as an irrigation water conveyance, rather than a river.”

Tule Lake, once larger than Upper Klamath Lake but now less than 15% of its original size, contains populations of both endangered species amounting to perhaps a few hundred fish represented by a few size classes of old fish (for example, 16-24 in; Scoppettone et al. 1995). Suckers in Tule Lake typically have higher condition factors and lower incidence of external parasites than suckers in other parts of the basin (USFWS 2002). The Tule Lake populations historically were maintained by spawning runs up the Lost River, which for reasons listed above now are extremely limited. Conditions within Tule Lake are deteriorating because of accumulation of sediment from agricultural sources. Alterations in water-management practices, however, could arrest deterioration. Some changes might even restore spawning runs. In 1999, the U.S. Bureau of Reclamation began releasing 30 cfs during the spawning and incubation period (April-June), which led to detectable spawning activity below Anderson Rose Dam within 2 days (USFWS 2002). Such spawning could presumably lead to juvenile recruitment, but monitoring for presence of juveniles is needed. Collection of larvae reported by Shively et al. (2000a) is additional evidence of reproduction. The relatively good condition of suckers in Tule Lake makes these populations valuable for the long-term survival of both species of suckers, especially given the continuation of fish kills in Upper Klamath Lake.

Conservation Status

Lost River suckers and shortnose suckers were declared endangered by California in 1974 (Moyle 2002); Oregon placed both Lost River suckers and shortnose suckers on its protected list in 1987. USFWS first listed both sucker species as candidate (Category 2) species in 1982. They were proposed for listing as endangered in 1987 and were designated as endangered species in 1988 (53 Fed. Reg. 27130 [1988]). Despite the controversy surrounding the species in recent years, only 13 written comments were received by USFWS during the comment period before listing: 12 of the comments favored listing, one expressed no opinion, and there were no comments opposing the listing. Reasons for listing are given in Chapter 6. A federal recovery plan has been developed (Stubbs and White 1993). Critical habitat was proposed in 1994 (59 Fed. Reg. 61744 [1994]) but has not yet been formalized, nor has a recovery team been designated.

CONCLUSIONS

Human activities in the upper basin have affected not only the listed suckers, but virtually all the native species, several of which are greatly diminished in distribution and abundance. In particular, bull trout and slender sculpin have become rare in the basin in recent years. The Lost River system, which appears to have changed the most in the last 30 yr was dominated by blue chub, tui chub, and the three native sucker species, but it is now dominated by nonnative species. Upper Klamath Lake also has a high abundance of nonnative species, and most of its native species appear to be declining. A downward trend may be common, in fact, to native fishes in most aquatic habitats in the upper Klamath basin, although documentation is weak. The overall status and biology of the fishes of the basin, except for the two endangered suckers, is poorly known or at least poorly recorded. Research over the last 15 yr has produced many unpublished reports and extensive data but very few peer-reviewed papers. Thus, the utility of the available information is hard to judge. One possible remedy would be to provide funding for postdoctoral scholars to compile information and write papers by working with university and agency scientists who have collected data.

Future status of the suckers and other native fishes and the spread of nonnative species cannot be judged without periodic basin-wide survey of fishes. Monitoring is a key feature of adaptive management (see Chapter 10). Also, most information on the biology and status of the suckers and other native fishes has not been published in peer-reviewed journals or books. Also, further studies on the systematics of Klamath basin fishes are needed so that managers can avoid being surprised by the discovery of new endangered species, as are studies of the effects of nonnative species on the listed suckers and other native fishes. Introductions or spread of nonnative species already in parts of the basin are major threats to native species. The Sacramento perch in particular has the potential to spread through the canal system from the Lost River to Upper Klamath Lake, where it could become a predator of juvenile suckers and other native fishes.

Populations of the two listed sucker species in the upper Klamath basin have declined greatly in overall abundance and breadth of distribution. Stable reproducing populations of the two species occur now only in Clear Lake and Gerber Reservoir (Gerber Reservoir has only shortnose suckers). The formerly large populations of the two suckers in Upper Klamath Lake are drastically reduced, although no quantitative estimates are available for former or present population sizes. The sucker populations showed a substantial increase in recruitment, as indicated by year class strength, following the end of fishing in 1987. While the populations of Upper Klamath Lake are reproducing and all age classes are present, they are not rebounding in abundance. Episodic mass mortality of large endangered suckers is one explanation for failure of the populations of Upper Klamath Lake to rebound. Other age classes may be adversely affected in other ways, but these mechanisms are not as well documented. Prolonged low concentration of dissolved oxygen during the late summer of some years is probably the direct cause of mass mortality in Upper Klamath Lake.

The two endangered sucker species are present at other locations, but at none of these locations are substantial numbers of all age classes present. Large suckers are present in the five mainstem reservoirs of the upper Klamath basin and in the upper and lower portions of the Lost River main stem, as well as Tule Lake, but there is no recruitment. Spawning occurs in the Lost River but does not sustain a population of juveniles in Tule Lake, as once was the case. Dewatering of Tule Lake and Lower Klamath Lake and large physical and chemical changes in the Lost River almost certainly are the cause for failure of endangered suckers in the Lost River below Clear Lake and Gerber Reservoir to show recruitment or increase in abundance.